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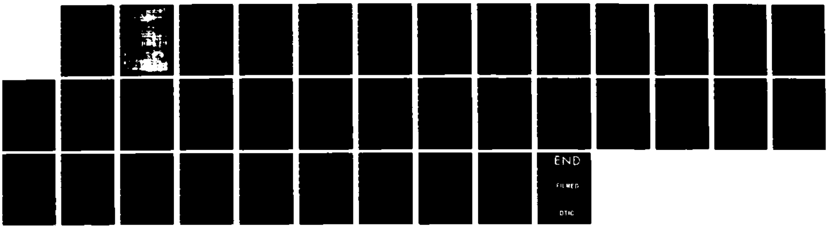

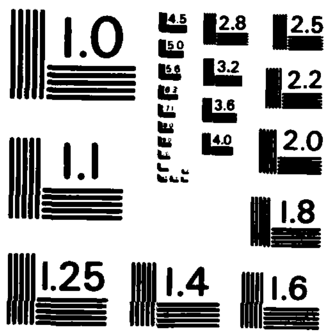

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AD-A160 643

USER'S GUIDE FOR A FORTRAN COMPUTER PROGRAM TO CALCULATE PROPELLER BLADE SECTIONS

by

D J ATKINS

Summary

A description is given of a FORTRAN computer program, known as MMG3, which generates cylindrical, planar or conical sections of propeller blades which are defined on conical surfaces. A data specification is given, with two test examples and details of the current implementation on an HP21MX system. A listing of the program is given separately in part B of the Memorandum.

42 pages
7 figures

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C O N T E N T S

LIST OF SYMBOLS

c	Chord length
c_1	Camber-line length
f	Camber value
l_{ij}, m_{ij}	Direction cosines used in rotation matrices
$\mathbf{L}, \mathbf{M}$	Rotation matrices used in co-ordinate transformation
r	Radial co-ordinate
r_h	Radius of hub where the stacking line intersects it
r_s	Radius of conical section at a particular stacking point
$t/2$	Half-thickness of blade section at any camber value
x/c	Chordwise distance expressed as a fraction of chord
x', y'	Co-ordinates of a point on blade section with respect to leading edge
x, y, z	Cartesian co-ordinates used in program
X, Y, Z	Rotated Cartesian co-ordinates
X', Y', Z'	Rotated Cartesian co-ordinates used for output
$\mathbf{X}_0, \mathbf{X}_1$	Translation vectors used in co-ordinate transformation
X_0, Y_0, Z_0	Elements of $\mathbf{X}_0$
X_1, Y_1, Z_1	Elements of $\mathbf{X}_1$
θ	Camber angle
ξ	Stagger angle
ϕ	Semi-angle of conical section
ψ	Output azimuthal angle
ψ_T	Skew angle
ω_T	Rake angle

INTRODUCTION

Propeller blade sections are normally designed on stream-surfaces, which may frequently with adequate accuracy be considered to be conical surfaces. For propeller manufacture, however, the sections are required on planes or cylindrical surfaces. A computer program, known as MMG3, exists to generate profiles of a propeller on cylindrical or plane surfaces, given propeller data quoted as sections on conical surfaces. The output data is in the form of listings, paper tape or graphical information.

The program was implemented on an ICL2970 computer, but owing to the closure of the 2970, it has been converted by City Computing Code Conversions, with some enhancement, to run on an HP21MX computer. The HP version, known as SMMG3, requires input data on either a disk file or paper tape, and produces output to one of the following devices: disk file (which can be listed), printer, paper tape, plotter or inspection paper tape. When plotter output is requested, a disk file is created and input to a program called CPLOT which carries out the plotting. Inspection paper tapes are produced in a special format suitable for input to a Ferranti measuring machine which measures the accuracy to which the blade has been manufactured. The tapes are produced by a program called CFERT using a disk file output by SMMG3. The programs CPLOT and CFERT were written in FORTRAN by City Computing and their use is transparent to the user of SMMG3.

The suite of programs SMMG3, CPLOT and CFERT is also being used with a further program known as BLAUTO, which has been written by City Computing in HP-BASIC to run on an HP9845C system. This program produces plots of blade/hub combinations with the options of either a single blade, the gap between two adjacent blades or all the blades attached to the hub. It can also produce plots showing machine tool cutter paths. Details of the programs BLAUTO, CPLOT and CFERT are beyond the scope of the present document, but any existing and future documentation produced by City Computing should be read in conjunction with it.

2. THEORY

The program can handle four different types of blade section, viz compressors or turbines with right- or left-hand screw. A plan view of each type of section on a conical hub is shown as Figure 1. In assembling the data, two separate problems must be considered: the description of each section on its conical surface, and the location of each section relative to the others. The first part follows aerofoil practice: a chord-line is drawn on the unwrapped conical surface, and a camber-line is drawn whose ends coincide with the ends of the chord-line. The thickness distribution is then added so that the normal to the camber-line joining the two surfaces is bisected by the camber-line (Figure 2). Note that Figure 2 represents the case of a right-hand compressor or a left-hand turbine. In the case of a left-hand compressor or right-hand turbine, the camber line lies above the chord line rather than below it. The camber line is either defined by a set of off-set values (i.e. a set of f, x/c pairs), or it is a circular arc specified simply by the camber angle θ. The thickness distribution is defined either by a set of half-thickness values (i.e. a set of $t/2$, x/c

pairs), with a leading-edge radius quoted to give improved accuracy in that region, or a built-in thickness distribution is used. Currently the only built-in thickness distribution available is a slightly modified C4 section (Figure 3). A thickness multiplier can be used to scale the values of thickness up or down. (When x/c values are used in data description, only a single set may be quoted, and these must apply throughout the whole case.)

(a) Definition of co-ordinate system and stacking line

The need for a stacking-point arises because of the need to locate the sections. On each chord line or camber line a point is chosen to be the stacking-point (in principle its selection is arbitrary). The angle between the chord-line and the line joining the stacking-point to the vertex of the cone is known as the stagger angle ξ. The line connecting all the stacking-points is the stacking-line (which in general will not be straight) and this must be located relative to some permanent axes. These are illustrated, for blades with right-hand screw, in Figure 4 and defined as follows: the origin is the intersection of the axis of rotation and a radius passing through the stacking-line at the hub, Ox increases aft, Or increases radially, $O\psi$ is measured from the radius through the stacking-line at the hub and increases clockwise looking forward, and Oy and Oz are defined by

$$z = r \cos\psi \tag{1}$$

$$y = r \sin\psi \tag{2}$$

For blades with left-hand screw, the axis $O\psi$ is reversed and y changes sign in (2). The system of axes Oxyz is used for the description of the input data and for the program's internal calculations. The stacking line is defined relative to the axes by the skew and rake angles ψ_T and ω_T respectively (Figures 4(a) and 4(b)).

Instead of quoting data on selected conical surfaces, the data (thickness, chord-length, stagger, etc.) may be quoted as polynomials of r_s. However, when data is quoted at specific points, then, for both radial and chordwise interpolation, a cubic is fitted to the most suitable four points.

(b) Detailed calculation of blade sections

Figure 5 shows the detail of calculating the co-ordinates x' and y' of a typical point P on the blade section with respect to the leading edge. Once again the Figure is for a right-hand compressor or left-hand turbine. For the other two cases Figures 5(a) and 5(b) should be reflected in the chord line. From Figure 5(a) (the general camber-line case)

$$x' = x_0' \mp (t/2) \sin\{\arctan(df/dx)\} \tag{3}$$

$$y' = f \pm (t/2) \cos\{\arctan(df/dx)\} \tag{4}$$

and thus given a value of x_0'/c $(0 < x_0'/c \le 1)$, x' and y' can be calculated. Similarly from Figure 5(b) (the circular-arc camber line case)

$$x' = (c/\theta)\sin(\theta/2) - (c/\theta \pm t/2)\sin(\theta/2 - \theta_1) \tag{5}$$

$$y' = (c/\theta \pm t/2)\cos(\theta/2 - \theta_1) - (c/\theta)\cos(\theta/2) \tag{6}$$

and thus given a value of θ_1/θ $(0 < \theta_1/\theta \le 1)$, x' and y' can again be calculated. The values of x_0'/c (or θ_1/θ) are specified by the user.

Figures 6(a)-(d) show each type of blade section on an unwrapped conical surface. Given the x' and y' values, Figures 4 and 6 enable the values of x, r and ψ to be calculated, as follows:

$$QP = (s - x')\sin\xi - y'\cos\xi \tag{7}$$

$$SQ = (s - x')\cos\xi + y'\sin\xi \tag{8}$$

$$AS = r_s/\sin\phi \tag{9}$$

$$(AP\sin\phi)^2 = \{r_s + (s-x')\cos\xi\sin\phi + y'\sin\xi\sin\phi\}^2 + \{QP\sin\phi\}^2 \tag{10}$$

$$\psi = QP/r_s - \{\psi_T - \arcsin(r_h/r_s\sin\psi_T)\} \qquad (\phi=0) \tag{11}$$

$$\psi = \operatorname{cosec}\phi\arcsin(QP/AP) - \{\psi_T - \arcsin(r_h/r_s\sin\psi_T)\} \quad (\phi\neq0) \tag{12}$$

$$x = -(s - x')\cos\xi - y'\sin\xi + (r_s - r_h)\tan\omega_T \qquad (\phi=0) \tag{13}$$

$$x = -(AP\sin\phi - r_s)\cot\phi + (r_s - r_h)\tan\omega_T \qquad (\phi\neq0) \tag{14}$$

$$r = AP\sin\phi \tag{15}$$

$$y = r\sin\psi \tag{16}$$

$$z = r\cos\psi \tag{17}$$

Equations (7) to (17) above are for a right-hand compressor. For a turbine, the terms in y' in (7), (8), (10) and (13) should have the opposite sign, and for a left-hand blade, y has the opposite sign in (16).

Figure 6 and equations (7) to (17) assume that the stacking point lies on the chord line. In the case of circular-arc camber lines only, the program can handle cases where the stacking point lies on the camber line. Figure 7 shows the details for a right-hand compressor; other similar diagrams can be drawn for the other three cases. The distances s and δx are given by

$$s = 2r \sin(q\theta/2) \sin\{\xi+(1-q)\theta/2\}/\sin\xi \tag{18}$$

$$\delta x = (2c_1/\theta) \sin(q\theta/2) \sin\{(1-q)\theta/2\}/\sin\xi \tag{19}$$

Equation (8) now becomes

$$SQ = (s - x') \cos\xi + y' \sin\xi - \delta x \tag{20}$$

and equations (7) and (9) to (17) apply unchanged apart from the modifications described above for other types of blade.

3. GENERATION OF OUTPUT SECTIONS USING ROTATION MATRICES

For propeller manufacture, blade sections are often required in planes that are rotated about the origin of the program's co-ordinate system. A further requirement is for the sections to be output as viewed from any angle, giving, for example, side and end elevations. These requirements are satisfied by the use of two rotation matrices $\underline{L}$ and $\underline{M}$, which are given by

$$\underline{L} = \begin{bmatrix} l_{11} & l_{12} & l_{13} \\ l_{21} & l_{22} & l_{23} \\ l_{31} & l_{31} & l_{33} \end{bmatrix} \qquad \underline{M} = \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix} \tag{21}$$

Both the matrices $\underline{L}$ and $\underline{M}$ should be valid rotation matrices with their elements being suitable direction cosines. If no rotation is to be used, then the unit matrix is input with (for example)

$$l_{11} = l_{22} = l_{33} = 1, \quad \text{all other } l_{ij} = 0$$

The facility also exists to use $\underline{L}$ and $\underline{M}$ in conjunction with linear translations $\underline{X}_0$ and $\underline{X}_1$, given by

$$\underline{X}_0 = (X_0, Y_0, Z_0) \qquad \underline{X}_1 = (X_1, Y_1, Z_1) \tag{22}$$

$\underline{X}_0$ and X_1 are not currently used at present, i.e. their elements are normally read in as zero.

In addition to the co-ordinate system Oxyz used in the program, the matrices **L** and **M** with their respective translation vectors $\mathbf{X}_0$ and $\mathbf{X}_1$ define two further co-ordinate systems O'XYZ and O''X'Y'Z' which are used in calculating the output blade profiles as described in Sections 3(a)-(c) below. The co-ordinates of points (X,Y,Z) and (X',Y',Z') are given in terms of x,y and z by the matrix equations.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} l_{11} & l_{12} & l_{13} \\ l_{21} & l_{22} & l_{23} \\ l_{31} & l_{32} & l_{33} \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} + \begin{bmatrix} X_0 \\ Y_0 \\ Z_0 \end{bmatrix} \qquad (23)$$

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} X_1 \\ Y_1 \\ Z_1 \end{bmatrix} \qquad (24)$$

The program calculates each point of a particular blade section in x, y, z co-ordinates and transforms to X, Y, Z co-ordinates using equation (23) and to X', Y', Z' co-ordinates using equation (24). The output data consists of a set of X' and Y' values (with a set of Z' values in the case of conical sections). The interpretation of the output data depends on the blade sections used and this is explained for each type of section below.

(a) Conical sections

A particular conical surface is specified by the radius r_s at the stacking point and the cone semi-angle Φ. For each chordwise station (x/c) the output co-ordinates x, y, z are evaluated and transformed to X', Y', Z' using the first matrix followed by the second. If listings are required, tables of X', Y' and Z' corresponding to a particular r_s are output. If plots are required, X' is plotted against Y', and the values of Z' are ignored.

(b) Plane sections

In this case, the value of r_s corresponding to a particular plane height is not known and has to be determined by iteration. For each chordwise station (x/c), starting with an initial guess of r_s, the co-ordinates x, y, z are evaluated and transformed to X, Y and Z using the first matrix. The method calculates the profile on the plane $Z=Z^*$ by repeating the process for a variety of different r_s iterating until $Z=Z^*$. In some cases (particularly with awkwardly-shaped blades or large rotations) the process may fail to converge, in which case an error message will be output. The final values of X, Y, Z are transformed using the second matrix to X', Y', Z' and for each plane height $Z=Z^*$ the values X' and Y' are either tabulated or plotted. The values of Z' are ignored.

To sum up, if the first matrix is unity, the plane sections will be calculated at z-heights vertically above the stacking point. If the second matrix is also unity, then the output data will consist of these sections as viewed from overhead. If the second matrix is not unity but a valid rotation matrix, then the same sections will be calculated, but be output as viewed looking down along the new Z' axis. If the first matrix is not unity but a valid rotation matrix, then the plane sections will be calculated at Z-heights in the rotated co-ordinate system. A further rotation, applied using the second matrix, will result in the same plane sections (calculated at Z-heights) being output as viewed looking down along the new Z' axis.

(c) Cylindrical sections

The output of cylindrical sections implies cylinders co-axial with O'X. The procedure is similar to that for plane sections except that to calculate the profile on a radius R^* the method calculates X, Y, Z using the first matrix as before and then computes $R = \sqrt{(Y^2+Z^2)}$ iterating until $R=R^*$. X', Y' and Z' are computed using the second matrix and for each radius R^*, X' and Y' are tabulated or plotted.

4. HP21MX IMPLEMENTATION AND CONTROL PROCEDURES

A brief document describing the HP implementation of MMG3 has been produced by City Computing in the form of a disc file, a listing of which is included as Appendix A. The HP version of the program (implemented in single precision and known as SMMG3) gives results using the test examples which agree with the original ICL2970 version to sufficient accuracy.

On the HP21MX commands are typed in and executed by pressing [RETURN]. The program SMMG3 can be run as follows: if listings only are required, type RUN SMMG3; otherwise type TR,MMG3S. Use of the latter command starts the initial dialogue. The system responds with

Input from paper tape (P) or file (F)

where the characters in brackets denote the expected response. The program will loop until an acceptable response is entered. If input from a file (F) is requested, then the query

Enter file name (max 6 characters)

asks for the name of a file. The first character should be alphabetic only and the remaining ones alphanumeric. The output device is requested using the query

Output Paper Tape (PT), file (F)
Printer (P), Plotter (PL), Inspection (I)

If output to file is requested, a file name will be asked for, viz

Enter output file name (max 6 characters)

A file name should be entered as above. On completion of the initial dialogue, the data file is read, from either disk or paper tape, according to the specification in Section 5 below.

5. DATA SPECIFICATION

There are several options available regarding the input of data which are summarized below:-

(a) Circular arc camber lines and C4 sections are used. In this case, NX=0, CF=0 or -1 and TD=0. The blade section parameters (camber, stagger, etc.) are input in the form of either polynomial coefficients (POL=0) or sectional values at a radius r_s (POL=1).

(b) Camber values are specified, but C4 sections are used. NX is positive, CF=1 and TD=0.

(c) Circular arc camber lines are specified, but a thickness distribution is input along with a leading edge radius. In this case, NX is positive, CF=0 or -1 and TD=1.

(d) Both camber and thickness are input with a leading edge radius. NX is positive, CF=1 and TD=1.

In cases (b), (c) and (d), sectional values must always be used (i.e. POL=1). The most widely used options are (a) and (d).

Owing to limitations in HP FORTRAN, the format of the data within each item is not completely free. Any restrictions are indicated with the particular item in the data specification, which follows below:

Item 01: one line containing a title of up to 40 characters which appears on the output data.

Item 02: one integer, NX, which has the following meaning:-

- NX=0 implies that both circular arc camber lines and C4 sections are used.
- NX>0 implies that prescribed camber f and/or thickness t/2 distributions are used. NX denotes the number of input chordwise stations at which f or t/2 are to be input.

Item 03: (Omit this item if NX=0)
NX real numbers which are the input chordwise stations $(x/c)_i$ at which f or t/2 are to be specified. (Use nine numbers per line for as many lines as are required.)

Item 04: one line containing four integers

TD code for type of thickness distribution used
- TD=0 C4 section to be used
- TD=1 thickness distribution to be specified

POL code for form of blade section parameters
- POL=0 NS polynomial coefficients to be specified
- POL=1 NS sectional values to be specified

CF code for type of camber-lines
- CF=-1 circular-arc camber lines, camber-line length specified
- CF= 0 circular-arc camber lines, chord length specified
- CF= 1 NX camber values to be specified, chord length specified

NS number of sections at which blade parameters are to be specified (if POL = 1) or number of polynomial coefficients (if POL = 0)

Item 05: For I = 1 to NS, the following data are required:

(a) One line containing eight real numbers:

R(I) r_s, the radius (in mm) at the stacking point of the relevant conical section. (If POL = 0, then set R(I) = 0.0, in which case the remaining numbers on this line refer to polynonial coefficients rather than sectional values.)

PHI(I) ϕ, cone semi-angle (in degrees)

ZI(I) $|\xi|$, absolute value of stagger angle (in degrees)

C(I) chord length c or camber-line length c_1(in mm), depending on CF

TM(I) tm, thickness multiplier (all the thicknesses for this section are multiplied by tm). If TD = 0, implying that C4 sections are used, then the thickness to chord ratio is (tm × 10)%. For a standard C4 section, set TD = 1.0

PSI(I) ψ_T, skew angle in degrees (down-wake skew is positive)

OMEGA(I) ω_T, rake angle in degrees (backward rake is positive)

TH(I) θ, camber angle (in degrees). If CF = 1, then set TH(I) = 0.0

(Omit sub-item (b) if CF $\neq$ 1.)
(b) NX real numbers which are the values of camber f (in mm) which correspond to the input chordwise stations $(x/c)_i$.
(Use nine numbers per line for as many lines as required.)

(Omit sub-items (c) and (d) if TD = 0.)
(c) One real number LER(I), the leading edge radius normalised with respect to the chord.

(d) NX real numbers which are the values of half-thickness $t/2$ (in mm) corresponding to the input chordwise stations $(x/c)_i$. (Use nine numbers per line for as many lines as required.)

Item 06: One line containing two real numbers

r_h Hub radius (in mm)

r_t Tip radius (in mm)

Item 07: Six lines containing data for the two rotation matrices and translation vectors, input in the following order:

line 1: l_{11} l_{12} l_{13} X_0

line 2: l_{21} l_{22} l_{23} Y_0

line 3: l_{31} l_{32} l_{33} Z_0

line 4: m_{11} m_{12} m_{13} X'_0

line 5: m_{21} m_{22} m_{23} Y'_0

line 6: m_{31} m_{32} m_{33} Z'_0

Item 08: One line containing three real numbers followed by three integers

SCAL output scaling factor. Immediately before values of X', Y' and Z' are output, they are scaled by a factor SCAL. This facility is useful, for example, if large scale plots are required.

Q q, fraction of the way along the chord (or camber line) from the leading edge of the stacking point.

QST index denoting whether the stacking point is on the chord line or the camber line.
QST = 0. Stacking point is on the chord line.
QST ≠ 0. Stacking point is on the camber line.

RL index denoting right- or left-hand screw.
RL = 1. Right-hand screw.
RL = -1. Left-hand screw.

CT index denoting compressor or turbine
CT = 1. Compressor (or rotor).
CT = -1. Turbine (or stator).

CP index denoting whether conical, plane or cylindrical output sections are required.
CP = -1. Conical sections.
CP = 0. Cylindrical sections.
CP = 1. Plane sections.

Item 09: one integer N which denotes the number of output points per section on each side of the blade. If plots are requested, the plotting routine calculates data at intermediate points by interpolation. The value of N must be greater than 2.

Item 10: one line containing two integers

IPRINT index denoting number of decimal places in output section coordinates
IPRINT = 3 three decimal places
IPRINT = 4 four decimal places
Any other value will result in no output being produced.

IPUNCH index controlling the output of inspection paper tape. This is not used in the current version of the program, as paper tape output is produced by program CPERT. The user should set IPUNCH = 0.

Item 11: N real numbers which are the chordwise stations $(x/c)_o$ at which section data are to be output. (Use ten numbers per line for as many lines as are required.)

Item 12: one integer NRZ which denotes the number of output sections required

Item 13: NRZ real numbers which are the values of r_s in the case of conical sections, Z (plane heights) in the case of plane sections and R (radii) in the case of cylindrical sections (all in mm). (Use ten numbers per line for as many lines as are required.)

6. TEST EXAMPLES

Data and output listings of a blade with circular arc camber lines and C4 sections (data option (a) in Section 5) are presented as Appendices B and C respectively. The corresponding listings of a blade with specified camber and thickness distribution (data option (d)) are in Appendices E and F. The corresponding plotter outputs are presented (in monochrome) as Appendices D and G. The data file in this case is identical to that used to produce the listings except for differences in the scale factor SCAL.

7. CONCLUDING REMARKS

There are plans to modify the program to handle more built-in thickness distributions with a consequent reduction in the amount of input data required. It is recommended that all the computer programs connected with propeller blade manufacture be fully documented and implemented in FORTRAN-77 on the VAX 11-785 installation as soon as practicable.

D J Atkins (SSO)

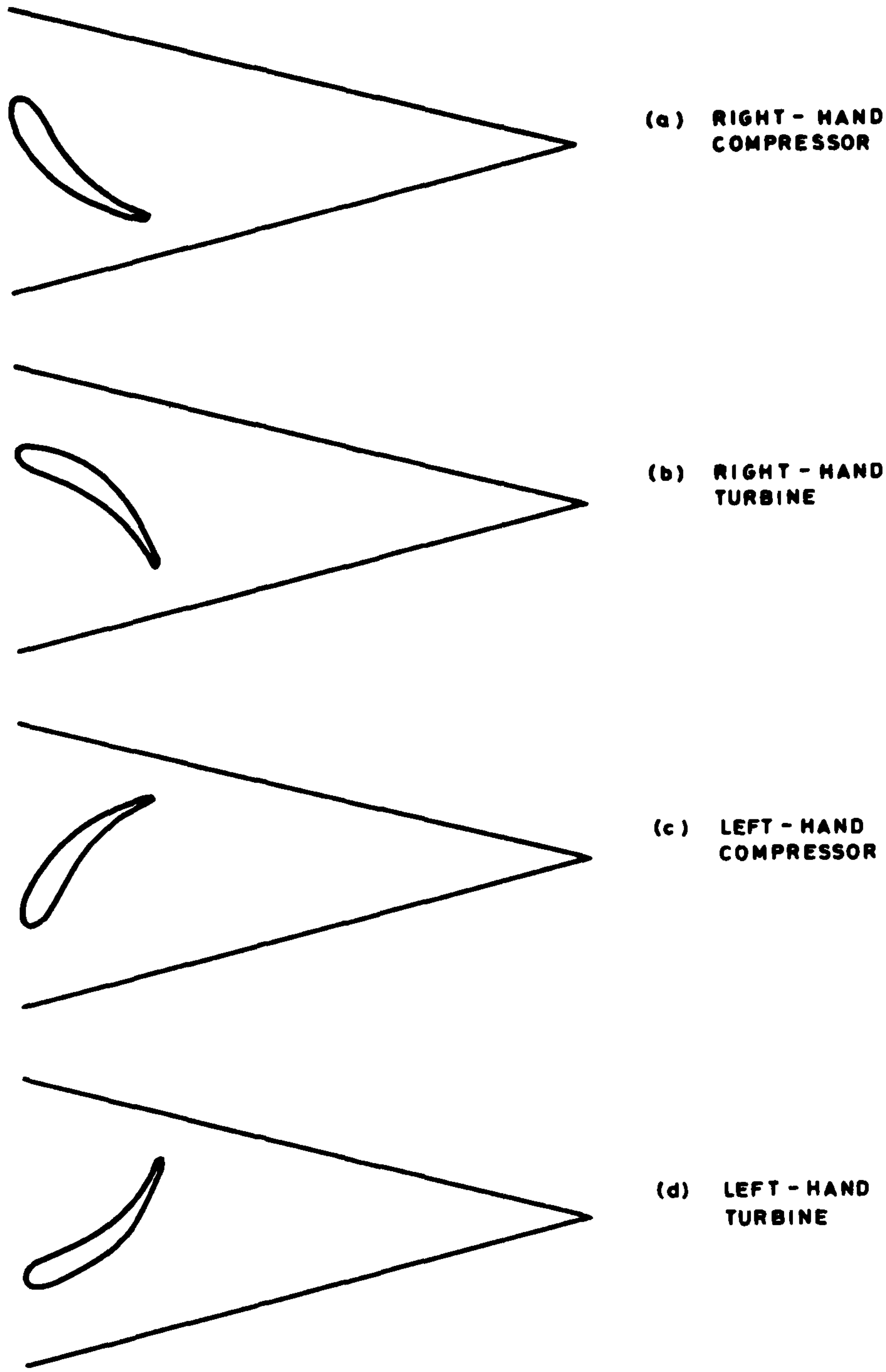


FIG. 1 PLAN VIEW OF DIFFERENT TYPES OF BLADE SECTIONS ON A CONICAL HUB

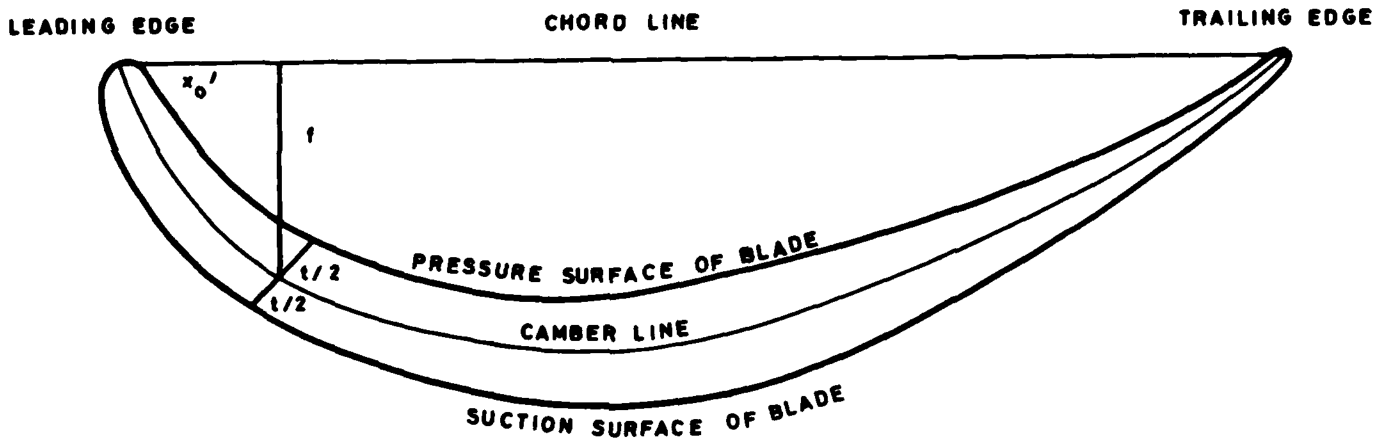


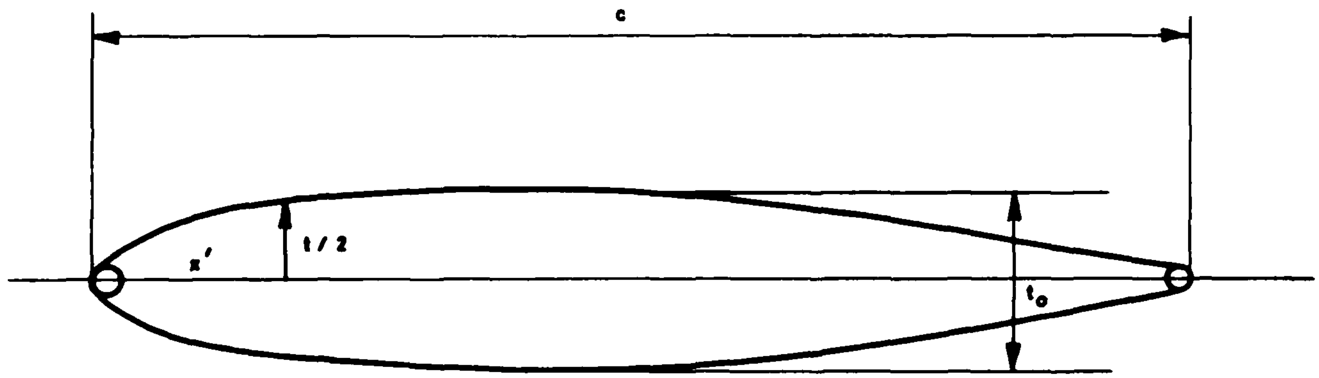
FIG. 2 DEFINITION OF CAMBER AND THICKNESS
(RIGHT - HAND COMPRESSOR OR LEFT - HAND TURBINE)

MAXIMUM THICKNESS $= t_o$

LEADING EDGE RADIUS $= 12\% \, t_o$

TRAILING EDGE RADIUS $= 6\% \, t_o$

$t_o / c = 10\%$

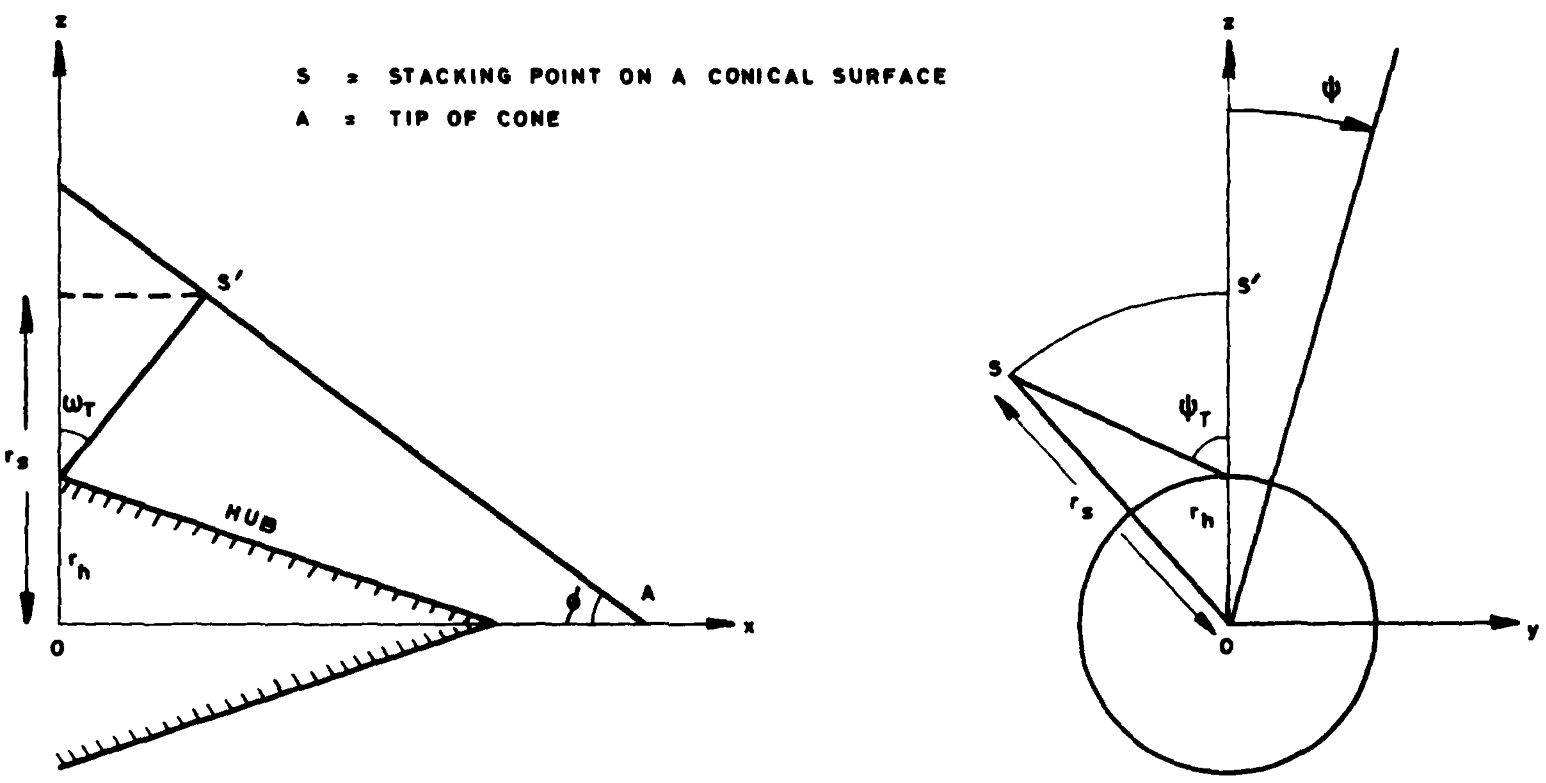


C4 (ARE) EQUATION : $(X < 0{\cdot}3) \pm t/2 = 0{\cdot}154920\sqrt{X} - 0{\cdot}061004\,X - 0{\cdot}283666\,X^2 + 0{\cdot}332527\,X^3$

$(X > 0{\cdot}3) \pm t/2 = 0{\cdot}040318 + 0{\cdot}066147X - 0{\cdot}118248X^2 + 0{\cdot}017783\,X^3$

$X = x'/c$

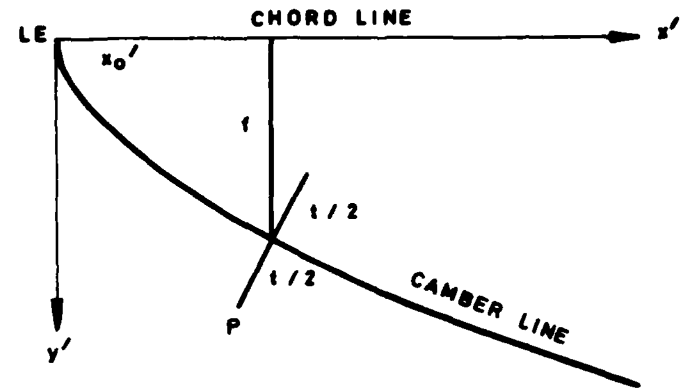
FIG. 3 BUILT IN THICKNESS DISTRIBUTION (MODIFIED C4 SECTION)



(a) Side view

(b) End view looking forward (Right-hand screw blade)

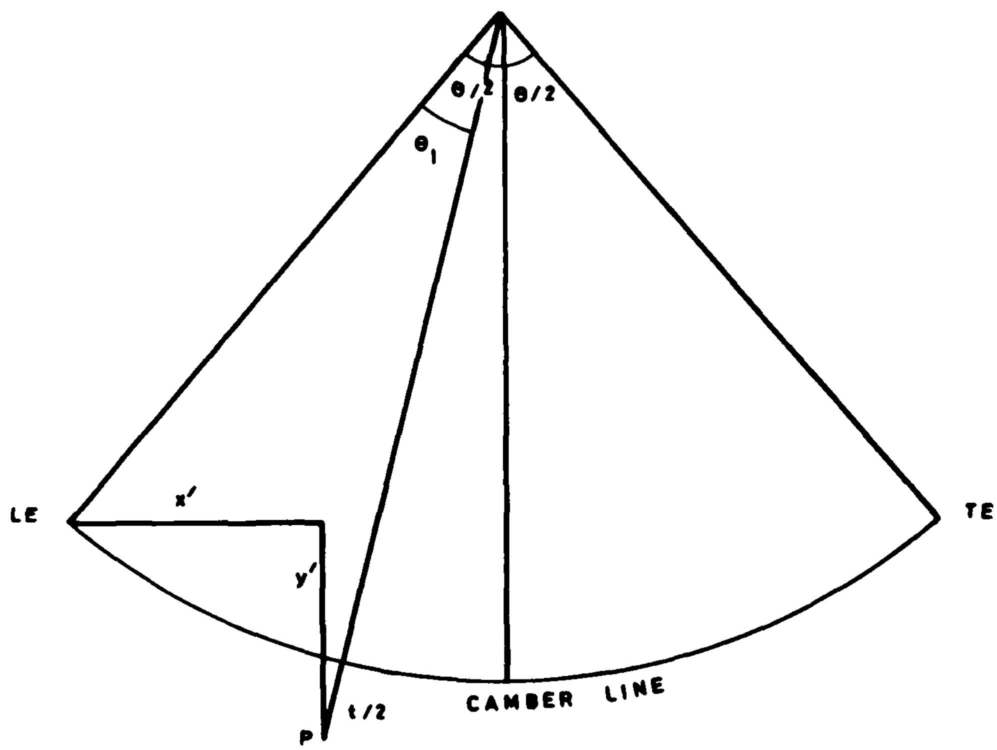
FIG. 4 BLADE STACKING NOTATION



(a) General Camber Line

LE = LEADING EDGE

TE = TRAILING EDGE



(b) Circular Arc Camber Line

FIG. 5 TYPES OF CAMBER LINE

(RIGHT-HAND COMPRESSOR OR LEFT-HAND TURBINE)

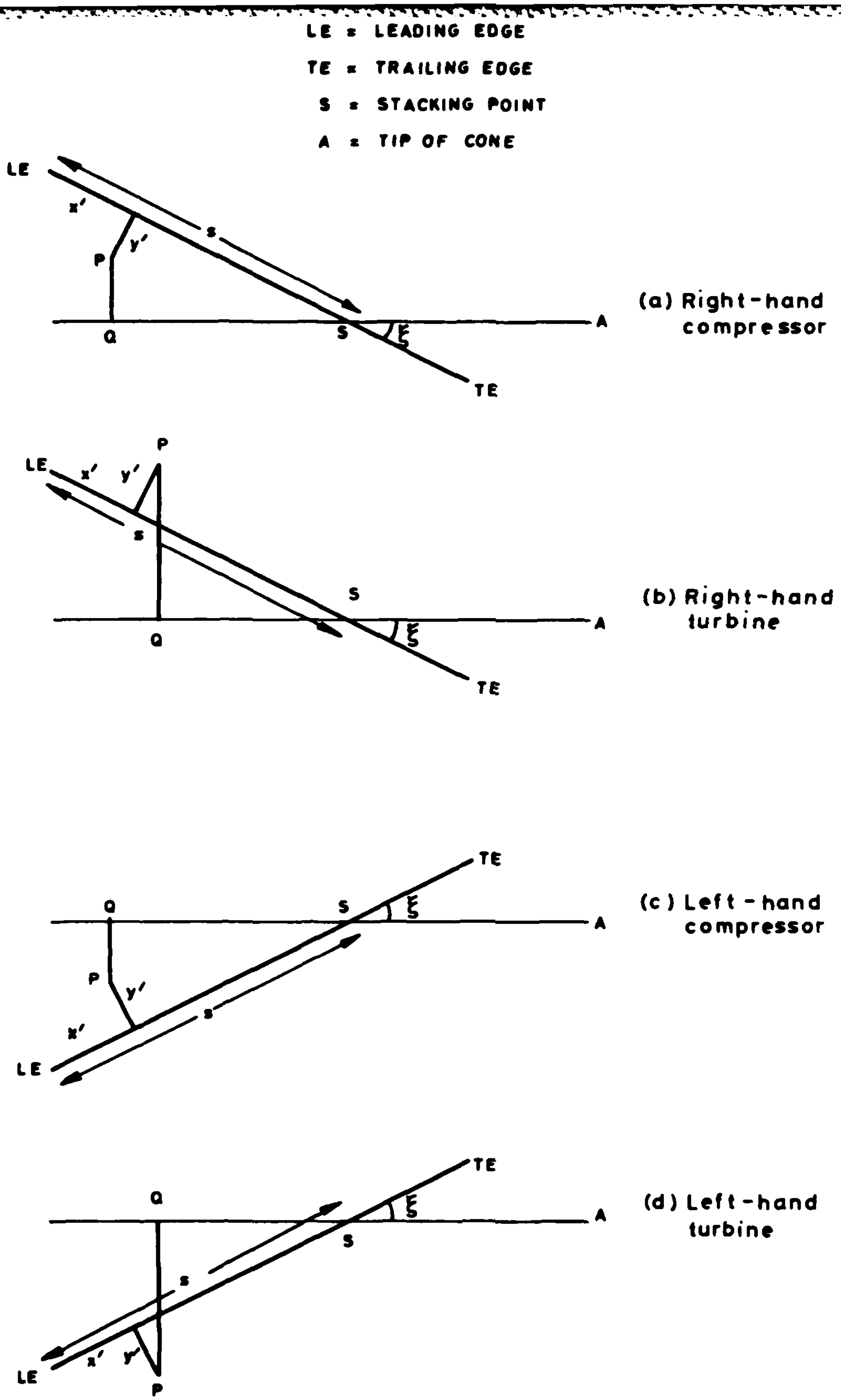


FIG. 6 BLADE SECTION ON UNWRAPPED CONICAL SURFACE (STACKING POINT LIES ON CHORD LINE)

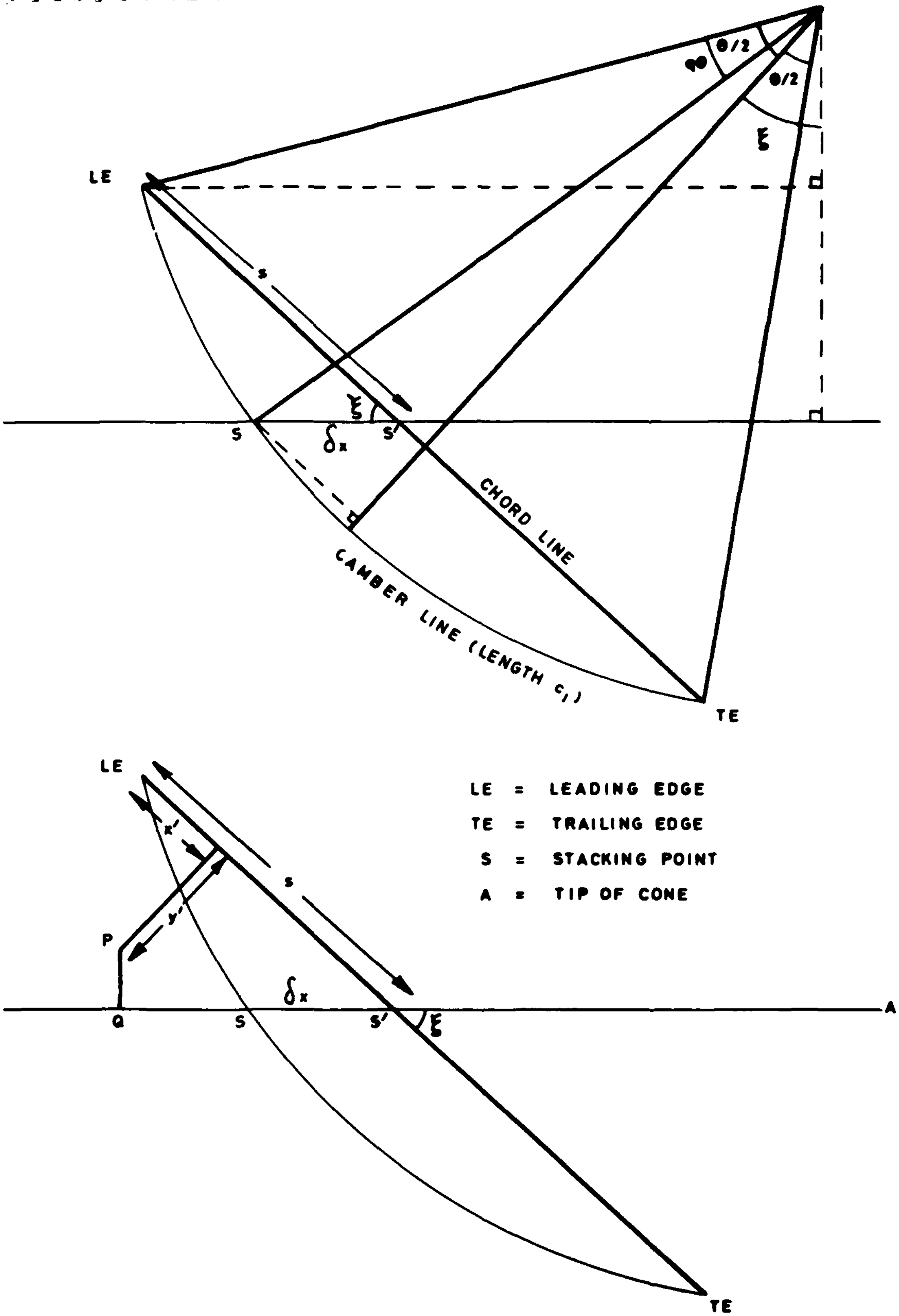


FIG. 7 BLADE SECTION ON UNWRAPPED CONICAL SURFACE
(STACKING POINT ON CIRCULAR ARC
CAMBER LINE, RIGHT-HAND COMPRESSOR)

```
      b) Double precision version.


          Source file                        &CMMG3
          -----------      and               &CPLOT


          To run type                        TR,MMG3
          -----------


          To recompile type                  RU,FTN4,&CMMG3,-,-
          -------------    and then          RU,FTN4,&CPLOT,-,-


          To reload                          TR,LCMMG3
          ---------        and then          TR,LCPLOT









 Program : CSPL2   ( replacement to Bklsprogs2 )
 ---------------

   This program takes its input from either paper tape or disc text file.
   The input data steam is selected by responding to the prompt from the
   user terminal.

   The output data device( printer,
                           paper tape,
                           disc file )  is selected by responding to
   another prompt on the users terminal.



      Source file                        &CSPL2
      -----------


      To run type                        RU,CSPL2
      -----------


      To recompile type                  RU,FTN4,&CSPL2,-,-
      -----------------


      To reload                          TR,LCSPL2
      ---------
```

APPENDIX A

Instructions for using HP21MX implementation

```
City Computing Code conversions .                    Date : 7 th Mav 1984.
--------------------------------

Marhine    : Hewlett Packard 21 MX .
- - - - - - - - - - - - - - - - -

Programs Converted  MMG3 and Bklsprogs2.
- - - - - - - - - - - - - - - - - - - - - -


  This contains instructions on how to run , compile and load the converted
  programs.



Program : MMG3
--------------

  This program takes its input from either paper tape or disc text file.
  The input data steam is selected by responding to the prompt from the
  user terminal.

  A typical input file format may be found on file MG3TES


  The output data device( printer,
                          paper tape,
                          disc file,
                          benson plotter )  is selected by responding to
  another prompt on the users terminal.


  This program exists in two forms

     a) Single precision version.

        Source file                    &SMMG3
        -----------     and            &CPLOT


        To run type                    TR,MMG3S
        -----------


        To recompile type              RU,FTN4,&SMMG3,-,-
        -------------   and then       RU,FTN4,&CPLOT,-,-


        To reload                      TR,LSMMG3
        ---------       and then       TR,LCPLOT
```

A P P E N D I X   B

Test example 1 - input data listing

```
MMG3 - 21MX

SAMPLE DESIGN DATA   Sections const
      0
      0         1         0         5
  47.0000   10.9900    6.7400   44.0000    1.0000    8.0000    0.0000   55.8500
  59.0000    9.6000   12.5000   43.0000    1.0000    8.0000    0.0000   45.6900
  71.0000    8.7300   18.2000   42.0000    1.0000    8.0000    0.0000   37.8600
  83.0000    8.2800   23.2300   41.0000    1.0000    8.0000    0.0000   31.6600
  95.0000    7.9900   27.9300   40.0000    1.0000    8.0000    0.0000   26.3200
  47.0000   95.0000
   1.0000    0.0000    0.0000    0.0000
   0.0000    1.0000    0.0000    0.0000
   0.0000    0.0000    1.0000    0.0000
   1.0000    0.0000    0.0000    0.0000
   0.0000    1.0000    0.0000    0.0000
   0.0000    0.0000    1.0000    0.0000
  1.00000   0.00000   0.00000         1         1        -1
     31
      4         0
   0.0000     .0012     .0025     .0050     .0075     .0100     .0150     .0200     .0300     .0400

    .0500     .0700     .0900     .1100     .1300     .1500     .1800     .2100     .2400     .2700

    .3000     .3500     .4000     .5000     .6000     .7000     .8000     .9000     .9500     .9800

   1.0000
      4
  47.0000   63.0000   79.0000   95.0000
```

APPENDIX C

Test example 1 - output listing

SAMPLE DESIGN DATA   Sections conic

CONICAL SECTIONS   RIGHT-HAND COMPRESSOR

RADIUS 47.000

X	Y	Z	X	Y	Z
0.0000	0.0000	47.0000	0.0000	0.0000	47.0000
-.0863	-.2281	47.0162	.1786	.1631	46.9650
-.0936	-.3402	47.0169	.2783	.2102	46.9455
-.0750	-.5162	47.0117	.4446	.2567	46.9130
-.0375	-.6650	47.0026	.5924	.2765	46.8841
.0099	-.7997	46.9913	.7306	.2825	46.8573
.1225	-1.0442	46.9646	.9900	.2713	46.8070
.2500	-1.2680	46.9343	1.2355	.2411	46.7595
.5324	-1.6780	46.8666	1.7024	.1489	46.6692
.8388	-2.0555	46.7920	2.1496	.0310	46.5025
1.1621	-2.4103	46.7122	2.5843	-.1004	46.4980
1.8453	-3.0698	46.5405	3.4296	-.3917	46.3323
2.5652	-3.6776	46.3562	4.2546	-.7036	46.1684
3.3137	-4.2432	46.1619	5.0673	-1.0261	46.0045
4.0856	-4.7722	45.9595	5.8721	-1.3534	45.8397
4.8773	-5.2679	45.7506	6.6722	-1.6817	45.6733
6.0965	-5.9545	45.4275	7.8603	-2.1702	45.4202
7.3476	-6.5780	45.0952	9.0638	-2.6477	45.1623
8.6255	-7.1429	44.7586	10.2625	-3.1088	44.8995
9.9257	-7.6532	44.4179	11.4669	-3.5489	44.6323
11.2448	-8.1124	44.0759	12.6789	-3.9639	44.3610
13.4778	-8.7702	43.5075	14.7180	-4.5920	43.9023
15.7473	-9.2941	42.9478	16.7807	-5.1385	43.4383
20.3650	-9.9392	41.8819	20.9720	-5.9830	42.5083
25.0352	-10.0509	40.9220	25.2414	-6.4884	41.5951
29.6927	-9.6375	40.0916	29.5743	-6.6447	40.7181
34.2706	-8.7116	39.3929	33.9519	-6.4411	39.8899
38.7012	-7.2896	38.8055	38.3509	-5.8655	39.1150
40.8402	-6.3991	38.5412	40.5496	-5.4342	38.7461
42.0944	-5.8091	38.3082	41.8662	-5.1286	38.5298
42.9174	-5.3932	38.2875	42.7424	-4.9051	38.3873

RADIUS 63.000

X	Y	Z	X	Y	Z
0.0000	-2.2430	62.9601	0.0000	-2.2430	62.9601
-.0895	-2.4622	62.9665	.1767	-2.0872	62.9366
-.0996	-2.5701	62.9638	.2742	-2.0426	62.9222
-.0866	-2.7398	62.9545	.4360	-1.9993	62.8972
-.0548	-2.8833	62.9429	.5793	-1.9817	62.8744
-.0131	-3.0134	62.9300	.7129	-1.9772	62.8527
.0878	-3.2497	62.9018	.9631	-1.9912	62.8115
.2034	-3.4662	62.8714	1.1995	-2.0235	62.7719
.4615	-3.8638	62.8060	1.6481	-2.1196	62.6956
.7427	-4.2309	62.7364	2.0769	-2.2406	62.6214
1.0401	-4.5769	62.6636	2.4929	-2.3772	62.5485
1.6694	-5.2236	62.5100	3.3003	-2.6790	62.4046
2.3329	-5.8242	62.3483	4.0865	-3.0043	62.2615
3.0227	-6.3884	62.1800	4.8591	-3.3433	62.1181
3.7339	-6.9215	62.0063	5.6229	-3.6906	61.9737
4.4633	-7.4269	61.8281	6.3808	-4.0424	61.8280
5.5861	-8.1385	61.5538	7.5113	-4.5730	61.6063
6.7380	-8.7996	61.2731	8.6388	-5.1011	61.3804
7.9143	-9.4147	60.9877	9.7671	-5.6216	61.1502
9.1111	-9.9876	60.6988	10.8909	-6.1303	60.9159
10.3253	-10.5218	60.4076	12.0366	-6.6232	60.6778
12.3818	-11.3316	59.9198	13.9487	-7.4029	60.2736
14.4745	-12.0414	59.4333	15.8816	-8.1285	59.8621
18.7498	-13.1587	58.4819	19.8097	-9.4143	59.0252
23.1125	-13.8724	57.5856	23.8195	-10.4741	58.1824
27.5232	-14.1852	56.7686	27.9088	-11.3005	57.3484
31.9421	-14.1030	56.0467	32.0730	-11.8853	56.5367
36.3292	-13.6340	55.4265	36.3059	-12.2193	55.7593
38.4984	-13.2576	55.1542	38.4455	-12.2894	55.3868
39.7893	-12.9871	55.0023	39.7359	-12.2996	55.1691
40.6449	-12.7885	54.9057	40.5986	-12.2931	55.0265

RADIUS 79.000

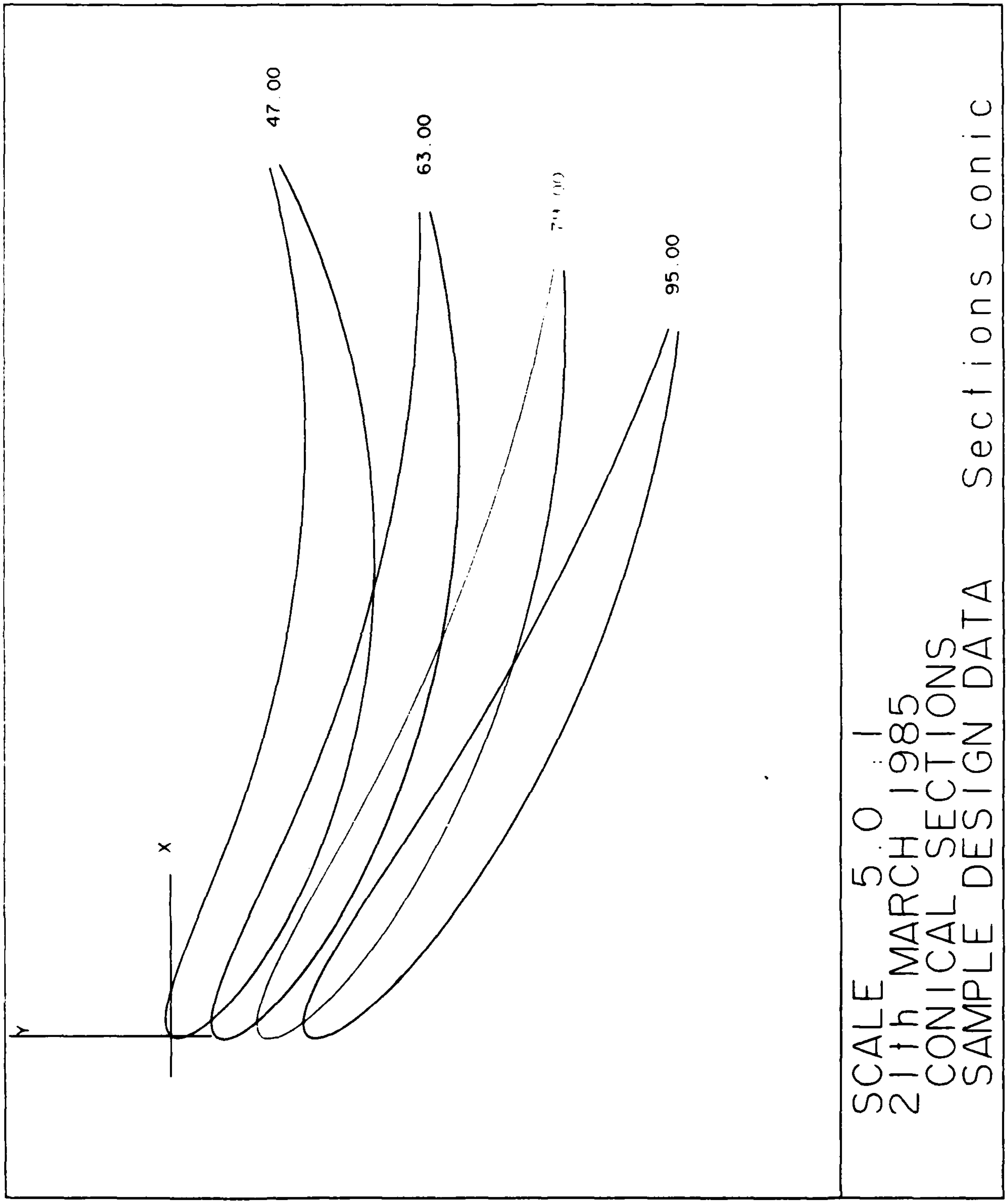
X	Y	Z	X	Y	Z
0.0000	-4.4794	78.8729	0.0000	-4.4794	78.8729
-.0965	-4.6875	78.8751	.1777	-4.3357	78.8547
-.1113	-4.7911	78.8710	.2736	-4.2963	78.8426
-.1068	-4.9550	78.8602	.4320	-4.2606	78.8212
-.0830	-5.0945	78.8478	.5712	-4.2491	78.8012
-.0492	-5.2213	78.8345	.7002	-4.2500	78.7820
.0364	-5.4527	78.8062	.9412	-4.2734	78.7452
.1369	-5.6656	78.7763	1.1679	-4.3142	78.7094
.3649	-6.0585	78.7133	1.5967	-4.4258	78.6398
.6161	-6.4232	78.6472	2.0050	-4.5616	78.5717
.8831	-6.7687	78.5786	2.4000	-4.7124	78.5043
1.4510	-7.4186	78.4357	3.1645	-5.0430	78.3707
2.0521	-8.0278	78.2865	3.9064	-5.3979	78.2372
2.6785	-8.6050	78.1321	4.6336	-5.7681	78.1031
3.3252	-9.1557	77.9733	5.3506	-6.1483	77.9679
3.9890	-9.6829	77.8108	6.0608	-6.5349	77.8312
5.0122	-10.4350	77.5611	7.1176	-7.1218	77.6230
6.0630	-11.1457	77.3054	8.1691	-7.7115	77.4106
7.1366	-11.8193	77.0449	9.2190	-8.2991	77.1939
8.2297	-12.4596	76.7805	10.2705	-8.8809	76.9729
9.3392	-13.0697	76.5128	11.3262	-9.4531	76.7476
11.2197	-14.0247	76.0612	13.0982	-10.3793	76.3638
13.1359	-14.9031	75.6056	14.8875	-11.2698	75.9704
17.0626	-16.4273	74.6956	18.5190	-12.9410	75.1596
21.0943	-17.6397	73.8066	22.2243	-14.4621	74.3245
25.2054	-18.5402	72.9594	26.0058	-15.8274	73.4747
29.3705	-19.1311	72.1707	29.8648	-17.0308	72.6200
33.5640	-19.4166	71.4529	33.8021	-18.0656	71.7702
35.6636	-19.4465	71.1234	35.7998	-18.5175	71.3502
36.9222	-19.4288	70.9356	37.0076	-18.7671	71.1005
37.7606	-19.4023	70.8145	37.8167	-18.9244	70.9352

RADIUS 95.000

X	Y	Z	X	Y	Z
0.0000	-6.7126	94.7626	0.0000	-6.7126	94.7626
-.1029	-6.9091	94.7629	.1783	-6.5815	94.7467
-.1223	-7.0083	94.7584	.2729	-6.5476	94.7357
-.1261	-7.1665	94.7471	.4272	-6.5200	94.7159
-.1100	-7.3019	94.7345	.5620	-6.5150	94.6973
-.0837	-7.4255	94.7211	.6866	-6.5216	94.6793
-.0128	7.6521	94.6931	.9181	-6.5549	94.6444
.0731	-7.8615	94.6639	1.1349	-6.6046	94.6105
.2720	8.2499	94.6028	1.5432	-6.7323	94.5440
.4943	-8.6124	94.5391	1.9305	6.8829	94.4787
.7323	-8.9573	94.4735	2.3043	-7.0480	94.4139
1.2416	-9.6101	94.3375	3.0250	-7.4065	94.2849
1.7833	-10.2264	94.1962	3.7220	-7.7853	94.1559
2.3492	-10.8147	94.0505	4.4031	-8.1881	94.0261
2.9348	-11.3799	93.9010	5.0731	-8.5977	93.8951
3.5369	-11.9251	93.7481	5.7350	-9.0150	93.7626
4.4658	-12.7102	93.5133	6.7176	-9.6503	93.5602
5.4208	-13.4609	93.2728	7.6925	-10.2918	93.3547
6.3975	-14.1813	93.0273	8.6638	-10.9352	93.1442
7.3923	-14.8749	92.7775	9.6347	-11.5766	92.9294
8.4024	-15.5447	92.5239	10.6078	-12.2128	92.7101
10.1150	-16.6130	92.0938	12.2385	-13.2561	92.3355
11.8610	-17.6219	91.6565	13.8819	-14.2765	91.7498
15.4454	-19.4594	90.7696	17.2092	-16.2472	91.1478
19.1388	-21.0544	89.8806	20.5945	-18.1216	90.3091
22.9240	-22.4059	89.0055	24.0421	-19.8954	89.4393
26.7843	-23.5144	88.1584	27.5564	-21.5639	88.5441
30.7026	-24.3821	87.3515	31.1403	-23.1220	87.6299
32.6784	-24.7265	86.9663	32.9592	-23.8579	87.1677
33.8679	-24.9040	86.7417	34.0594	-24.2852	86.8893
34.6625	-25.0120	86.5948	34.7966	-24.5640	86.7034

A P P E N D I X   D

Test example 1 - plotter output



A P P E N D I X   E

Test example 2 - input data listing

```
' MMG3 - 21MX

 C1 AFT PROP 5 BLADES PLANELIST 0ROT
    30
  0.0000     .0010     .0020     .0030     .0050     .0075     .0125     .0250     .0500
   .0750     .1000     .1500     .2000     .2500     .3000     .3500     .4000     .4500
   .5000     .5500     .6000     .6500     .7000     .7500     .8000     .8500     .9000
   .9500     .9750    1.0000
     1         1         1        20
 27.4990    0.0000   40.6100   38.5780     .1395    0.0000    0.0000    0.0000
  0.0000     .0010     .0010     .0010     .0020     .0030     .0060     .0100     .0150
   .0160     .0120    -.0080    -.0420    -.0810    -.1270    -.1740    -.2160    -.2470
  -.2700    -.2780    -.2700    -.2470    -.2120    -.1700    -.1230    -.0770    -.0390
  -.0120    -.0040    0.0000
   .0087
  0.0000     .0299     .0422     .0516     .0665     .0812     .1044     .1466     .2066
   .2525     .2907     .3521     .4000     .4363     .4637     .4832     .4952     .5000
   .4962     .4846     .4653     .4383     .4035     .3612     .3110     .2532     .1877
   .1143     .0748     .0333
 33.0070    0.0000   39.1800   44.2980     .1212    0.0000    0.0000    0.0000
  0.0000     .0010     .0020     .0030     .0050     .0080     .0140     .0310     .0750
   .1260     .1770     .2700     .3540     .4210     .4740     .5140     .5400     .5580
   .5670     .5670     .5580     .5400     .5050     .4610     .3940     .3190     .2260
   .1200     .0620    0.0000
   .0066
  0.0000     .0299     .0422     .0516     .0665     .0812     .1044     .1466     .2066
   .2525     .2907     .3521     .4000     .4363     .4637     .4832     .4952     .5000
   .4962     .4846     .4653     .4383     .4035     .3612     .3110     .2532     .1877
   .1143     .0748     .0333
 35.7570    0.0000   38.6800   46.7920     .1145    0.0000    0.0000    0.0000
  0.0000     .0020     .0040     .0070     .0110     .0170     .0280     .0600     .1310
   .2080     .2850     .4300     .5620     .6740     .7630     .8380     .8890     .9260
   .9450     .9450     .9310     .8940     .8280     .7440     .6270     .4960     .3420
   .1780     .0910    0.0000
   .0059
  0.0000     .0299     .0422     .0516     .0665     .0812     .1044     .1466     .2066
   .2525     .2907     .3521     .4000     .4363     .4637     .4832     .4952     .5000
   .4962     .4846     .4653     .4383     .4035     .3612     .3110     .2532     .1877
   .1143     .0748     .0333
 38.5070    0.0000   38.2900   48.9230     .1089    0.0000    0.0000    0.0000
  0.0000     .0040     .0080     .0120     .0190     .0290     .0490     .0990     .2010
   .3040     .4060     .5970     .7630     .9100    1.0320    1.1300    1.2080    1.2570
  1.2820    1.2820    1.2570    1.1990    1.1110     .9880     .8320     .6510     .4500
   .2300     .1160    0.0000
   .0053
  0.0000     .0299     .0422     .0516     .0665     .0812     .1044     .1466     .2066
   .2525     .2907     .3521     .4000     .4363     .4637     .4832     .4952     .5000
   .4962     .4846     .4653     .4383     .4035     .3612     .3110     .2532     .1877
   .1143     .0748     .0333
 41.2660    0.0000   38.0400   50.7270     .1043    0.0000    0.0000    0.0000
  0.0000     .0060     .0120     .0180     .0310     .0460     .0750     .1480     .2840
   .4120     .5330     .7610     .9640    1.1360    1.2780    1.3950    1.4810    1.5370
  1.5620    1.5570    1.5220    1.4460    1.3340    1.1820     .9890     .7710     .5330
   .2740     .1380    0.0000
   .0049
  0.0000     .0299     .0422     .0516     .0665     .0812     .1044     .1466     .2066
   .2525     .2907     .3521     .4000     .4363     .4637     .4832     .4952     .5000
   .4962     .4846     .4653     .4383     .4035     .3612     .3110     .2532     .1877
   .1143     .0748     .0333
 44.0150    0.0000   37.9800   52.2470     .1004    0.0000    0.0000    0.0000
```

0.0000	.0080	.0160	.0230	.0390	.0580	.0960	.1860	.3550
.5100	.6530	.9140	1.1390	1.3320	1.4940	1.6200	1.7080	1.7660
1.7920	1.7760	1.7240	1.6300	1.4940	1.3170	1.1020	.8570	.5850
.3030	.1550	0.0000						
.0045								
0.0000	.0299	.0422	.0516	.0665	.0812	.1044	.1466	.2066
.2525	.2907	.3521	.4000	.4363	.4637	.4832	.4952	.5000
.4962	.4846	.4653	.4383	.4035	.3612	.3110	.2532	.1877
.1143	.0748	.0333						
46.7650	0.0000	38.1200	53.4760	.0971	0.0000	0.0000	0.0000	
0.0000	.0090	.0180	.0270	.0450	.0670	.1110	.2160	.4120
.5910	.7540	1.0430	1.2890	1.4970	1.6680	1.8020	1.8930	1.9470
1.9630	1.9360	1.8660	1.7540	1.5990	1.4010	1.1660	.9040	.6150
.3160	.1610	0.0000						
.0042								
0.0000	.0299	.0422	.0516	.0665	.0812	.1044	.1466	.2066
.2525	.2907	.3521	.4000	.4363	.4637	.4832	.4952	.5000
.4962	.4846	.4653	.4383	.4035	.3612	.3110	.2532	.1877
.1143	.0748	.0333						
49.5150	0.0000	38.4800	54.3690	.0942	0.0000	0.0000	0.0000	
0.0000	.0100	.0200	.0300	.0490	.0740	.1220	.2370	.4510
.6450	.8210	1.1310	1.3970	1.6150	1.7890	1.9190	2.0060	2.0550
2.0610	2.0230	1.9410	1.8160	1.6420	1.4300	1.1850	.9130	.6200
.3150	.1590	0.0000						
.0040								
0.0000	.0299	.0422	.0516	.0665	.0812	.1044	.1466	.2066
.2525	.2907	.3521	.4000	.4363	.4637	.4832	.4952	.5000
.4962	.4846	.4653	.4383	.4035	.3612	.3110	.2532	.1877
.1143	.0748	.0333						
52.2560	0.0000	39.1000	54.9180	.0917	0.0000	0.0000	0.0000	
0.0000	.0100	.0210	.0310	.0520	.0770	.1270	.2480	.4720
.6740	.8570	1.1750	1.4440	1.6640	1.8340	1.9610	2.0480	2.0870
2.0810	2.0320	1.9440	1.8070	1.6310	1.4110	1.1640	.8900	.6040
.3020	.1500	0.0000						
.0038								
0.0000	.0299	.0422	.0516	.0665	.0812	.1044	.1466	.2066
.2525	.2907	.3521	.4000	.4363	.4637	.4832	.4952	.5000
.4962	.4846	.4653	.4383	.4035	.3612	.3110	.2532	.1877
.1143	.0748	.0333						
55.0240	0.0000	40.0400	55.1120	.0896	0.0000	0.0000	0.0000	
0.0000	.0110	.0220	.0330	.0540	.0810	.1330	.2580	.4850
.6860	.8650	1.1740	1.4330	1.6420	1.8020	1.9180	1.9950	2.0280
2.0170	1.9620	1.8740	1.7360	1.5600	1.3450	1.0970	.8320	.5620
.2810	.1400	0.0000						
.0036								
0.0000	.0299	.0422	.0516	.0665	.0812	.1044	.1466	.2066
.2525	.2907	.3521	.4000	.4363	.4637	.4832	.4952	.5000
.4962	.4846	.4653	.4383	.4035	.3612	.3110	.2532	.1877
.1143	.0748	.0333						
57.7740	0.0000	41.2900	54.9180	.0876	0.0000	0.0000	0.0000	
0.0000	.0110	.0230	.0340	.0560	.0840	.1370	.2630	.4830
.6710	.8350	1.1200	1.3560	1.5430	1.6860	1.7850	1.8510	1.8730
1.8620	1.8120	1.7240	1.5980	1.4330	1.2300	1.0050	.7580	.5050
.2470	.1210	0.0000						
.0034								
0.0000	.0299	.0422	.0516	.0665	.0812	.1044	.1466	.2066
.2525	.2907	.3521	.4000	.4363	.4637	.4832	.4952	.5000
.4962	.4846	.4653	.4383	.4035	.3612	.3110	.2532	.1877
.1143	.0748	.0333						
60.5230	0.0000	42.7400	54.2810	.0859	0.0000	0.0000	0.0000	

0.0000	.0110	.0220	.0330	.0540	.0810	.1320	.2500	.4510
.6170	.7600	1.0100	1.2100	1.3680	1.4930	1.5800	1.6200	1.6500
1.6390	1.5960	1.5140	1.4060	1.2590	1.0800	.8790	.6620	.4400
.2170	.1070	0.0000						
.0033								
0.0000	.0299	.0422	.0516	.0665	.0812	.1044	.1466	.2066
.2525	.2907	.3521	.4000	.4363	.4637	.4832	.4952	.5000
.4962	.4846	.4653	.4383	.4035	.3612	.3110	.2532	.1877
.1143	.0748	.0333						
63.2730	0.0000	44.2700	53.1490	.0845	0.0000	0.0000	0.0000	
0.0000	.0090	.0180	.0270	.0450	.0670	.1090	.2080	.3770
.5170	.6380	.8450	1.0100	1.1430	1.2440	1.3180	1.3610	1.3820
1.3710	1.3340	1.2700	1.1800	1.0580	.9140	.7440	.5630	.3770
.1860	.0920	0.0000						
.0032								
0.0000	.0299	.0422	.0516	.0665	.0812	.1044	.1466	.2066
.2525	.2907	.3521	.4000	.4363	.4637	.4832	.4952	.5000
.4962	.4846	.4653	.4383	.4035	.3612	.3110	.2532	.1877
.1143	.0748	.0333						
66.0320	0.0000	45.7700	51.4600	.0832	0.0000	0.0000	0.0000	
0.0000	.0070	.0130	.0200	.0330	.0490	.0800	.1510	.2730
.3760	.4680	.6380	.7720	.8800	.9670	1.0340	1.0700	1.0910
1.0860	1.0600	1.0090	.9370	.8440	.7310	.6020	.4630	.3140
.1600	.0810	0.0000						
.0031								
0.0000	.0299	.0422	.0516	.0665	.0812	.1044	.1466	.2066
.2525	.2907	.3521	.4000	.4363	.4637	.4832	.4952	.5000
.4962	.4846	.4653	.4383	.4035	.3612	.3110	.2532	.1877
.1143	.0748	.0333						
68.7820	0.0000	47.2200	49.1170	.0820	0.0000	0.0000	0.0000	
0.0000	.0030	.0060	.0090	.0150	.0220	.0370	.0750	.1520
.2280	.3000	.4270	.5350	.6290	.7020	.7560	.7960	.8100
.8100	.7910	.7560	.7070	.6390	.5600	.4670	.3590	.2460
.1280	.0660	0.0000						
.0030								
0.0000	.0299	.0422	.0516	.0665	.0812	.1044	.1466	.2066
.2525	.2907	.3521	.4000	.4363	.4637	.4832	.4952	.5000
.4962	.4846	.4653	.4383	.4035	.3612	.3110	.2532	.1877
.1143	.0748	.0333						
71.5320	0.0000	48.7000	45.9780	.0810	0.0000	0.0000	0.0000	
0.0000	.0010	.0020	.0020	.0040	.0070	.0120	.0280	.0690
.1180	.1700	.2670	.3540	.4230	.4830	.5290	.5610	.5750
.5750	.5610	.5380	.5010	.4550	.4000	.3360	.2620	.1790
.0920	.0470	0.0000						
.0029								
0.0000	.0299	.0422	.0516	.0665	.0812	.1044	.1466	.2066
.2525	.2907	.3521	.4000	.4363	.4637	.4832	.4952	.5000
.4962	.4846	.4653	.4383	.4035	.3612	.3110	.2532	.1877
.1143	.0748	.0333						
74.2820	0.0000	50.3200	41.6460	.0804	0.0000	0.0000	0.0000	
0.0000	0.0000	.0010	.0010	.0020	.0030	.0060	.0150	.0420
.0760	.1120	.1790	.2370	.2870	.3290	.3580	.3790	.3870
.3830	.3750	.3540	.3290	.2960	.2580	.2170	.1670	.1120
.0580	.0300	0.0000						
.0029								
0.0000	.0299	.0422	.0516	.0665	.0812	.1044	.1466	.2066
.2525	.2907	.3521	.4000	.4363	.4637	.4832	.4952	.5000
.4962	.4846	.4653	.4383	.4035	.3612	.3110	.2532	.1877
.1143	.0748	.0333						
77.0400	0.0000	52.2700	35.6160	.0804	0.0000	0.0000	0.0000	

```
  0.0000     .0020     .0040     .0070     .0110     .0160     .0260     .0490     .0890
   .1210     .1460     .1850     .2170     .2390     .2530     .2600     .2600     .2530
   .2420     .2280     .2100     .1890     .1640     .1350     .1070     .0750     .0430
   .0180     .0080    0.0000
   .0029
  0.0000     .0299     .0422     .0516     .0665     .0812     .1044     .1466     .2066
   .2525     .2907     .3521     .4000     .4363     .4637     .4832     .4952     .5000
   .4962     .4846     .4653     .4383     .4035     .3612     .3110     .2532     .1877
   .1143     .0748     .0333
 79.7900    0.0000   54.5900   26.4640     .0807    0.0000    0.0000    0.0000
  0.0000     .0010     .0030     .0040     .0070     .0100     .0160     .0290     .0480
   .0610     .0690     .0790     .0850     .0820     .0740     .0660     .0580     .0480
   .0370     .0320     .0260     .0210     .0130     .0080    0.0000    -.0080    -.0110
  -.0080    -.0050    0.0000
   .0029
  0.0000     .0299     .0422     .0516     .0665     .0812     .1044     .1466     .2066
   .2525     .2907     .3521     .4000     .4363     .4637     .4832     .4952     .5000
   .4962     .4846     .4653     .4383     .4035     .3612     .3110     .2532     .1877
   .1143     .0748     .0333
 82.5400    0.0000   56.0300   11.5560     .0771    0.0000    0.0000    0.0000
  0.0000    0.0000     .0010     .0010     .0020     .0020     .0040     .0070     .0120
   .0150     .0180     .0210     .0180     .0150     .0090     .0020    -.0030    -.0070
  -.0090    -.0090    -.0070    -.0050    -.0030    -.0030    -.0030    -.0050    -.0060
  -.0030    -.0010    0.0000
   .0027
  0.0000     .0299     .0422     .0516     .0665     .0812     .1044     .1466     .2066
   .2525     .2907     .3521     .4000     .4363     .4637     .4832     .4952     .5000
   .4962     .4846     .4653     .4383     .4035     .3612     .3110     .2532     .1877
   .1143     .0748     .0333
 27.4990   82.5400
  1.0000    0.0000    0.0000    0.0000
  0.0000    1.0000    0.0000    0.0000
  0.0000    0.0000    1.0000    0.0000
  1.0000    0.0000    0.0000    0.0000
  0.0000    1.0000    0.0000    0.0000
  0.0000    0.0000    1.0000    0.0000
 2.00000    .50000         0        -1
1         1
      31
       4         0
  0.0000     .0012     .0025     .0050     .0075     .0100     .0150     .0200     .0300     .0400

   .0500     .0700     .0900     .1100     .1300     .1500     .1800     .2100     .2400     .2700

   .3000     .3500     .4000     .5000     .6000     .7000     .8000     .9000     .9500     .9800

  1.0000
       4
 27.0000   40.0000   60.0000   80.0000
```

A P P E N D I X F

Test example 2 - output listing

C1 AFT PROP 5 BLADES PLANELIST 0ROT

PLANE SECTIONS LEFT-HAND COMPRESSOR

HEIGHT 27.000

X	Y	X	Y
-31.5403	-25.5376	-31.5403	-25.5376
-31.6319	-25.1866	-31.2666	-25.7509
-31.5976	-24.9992	-31.1173	-25.8033
-31.5337	-24.7136	-30.8157	-25.8181
-31.4306	-24.4542	-30.5547	-25.8048
-31.3229	-24.2173	-30.3006	-25.7690
-31.0733	-23.7685	-29.8280	-25.6690
-30.8083	-23.3499	-29.3716	-25.5437
-30.2654	-22.5744	-28.4806	-25.2336
-29.7066	-21.8314	-27.6198	-24.8893
-29.1341	-21.1182	-26.7847	-24.5176
-27.9774	-19.7359	-25.1569	-23.7441
-26.8059	-18.4070	-23.5800	-22.9419
-25.6292	-17.1222	-22.0409	-22.1237
-24.4514	-15.8757	-20.5307	-21.2932
-23.2740	-14.6627	-19.0469	-20.4529
-21.5144	-12.8944	-16.8638	-19.1845
-19.7662	-11.1888	-14.7288	-17.8997
-18.0199	-9.5296	-12.6413	-16.5995
-16.2700	-7.9083	-10.5975	-15.2886
-14.5312	-6.3310	-8.5942	-13.9684
-11.6476	-3.7704	-5.3261	-11.7275
-8.7776	-1.2841	-2.1506	-9.4249
-3.0041	3.5643	3.8822	-4.5814
2.9123	8.2870	9.5250	.6827
9.1663	12.9633	14.8319	6.3487
15.9320	17.5280	20.0552	12.3754
23.3259	21.8635	25.5450	18.6945
27.2737	23.8934	28.5202	21.9439
29.7160	25.9642	30.4052	23.9212
31.3752	25.8242	31.7065	25.2511

HEIGHT 40.000

X	Y	X	Y
-40.7281	-31.0757	-40.7281	-31.0757
-40.8686	-30.7362	-40.6915	-31.2284
-40.8572	-30.5427	-40.2064	-31.2369
-40.8037	-30.2225	-39.8680	-31.1839
-40.7037	-29.9245	-39.5747	-31.1114
-40.5935	-29.6485	-39.2912	-31.0189
-40.3421	-29.1271	-38.7554	-30.8038
-40.0674	-28.6306	-38.2426	-30.5678
-39.4728	-27.6834	-37.2594	-30.0580
-38.8478	-26.7722	-36.3047	-29.5249
-38.1982	-25.8938	-35.3738	-28.9712
-36.8679	-24.1814	-33.5439	-27.8432
-35.5038	-22.5245	-31.7517	-26.6919
-34.1233	-20.9103	-29.9836	-25.5208
-32.7271	-19.3257	-28.2422	-24.3387
-31.3168	-17.7677	-26.5239	-23.1484
-27.1824	-15.4714	-23.9789	-21.3581
-27.0227	-13.2270	-21.4747	-19.5616
-24.8418	-11.0324	-19.0024	-17.7578
-22.6409	-8.8797	-16.5577	-15.9499
-20.4252	-6.7689	-14.1343	-14.1337
-16.6933	-3.3296	-10.1497	-11.0921
-12.8967	.0188	-6.2263	-8.0371
-5.0645	6.4072	1.4922	-1.8611
3.1509	12.3808	9.0898	4.4493
11.8444	17.8857	16.6996	10.8531
21.0286	22.8560	24.4842	17.3387
30.6128	27.3227	32.5459	23.9761
35.5463	29.3972	36.6795	27.3560
38.5495	30.5954	39.1949	29.4047
40.5698	31.3730	40.8867	30.7781

HEIGHT 60.000

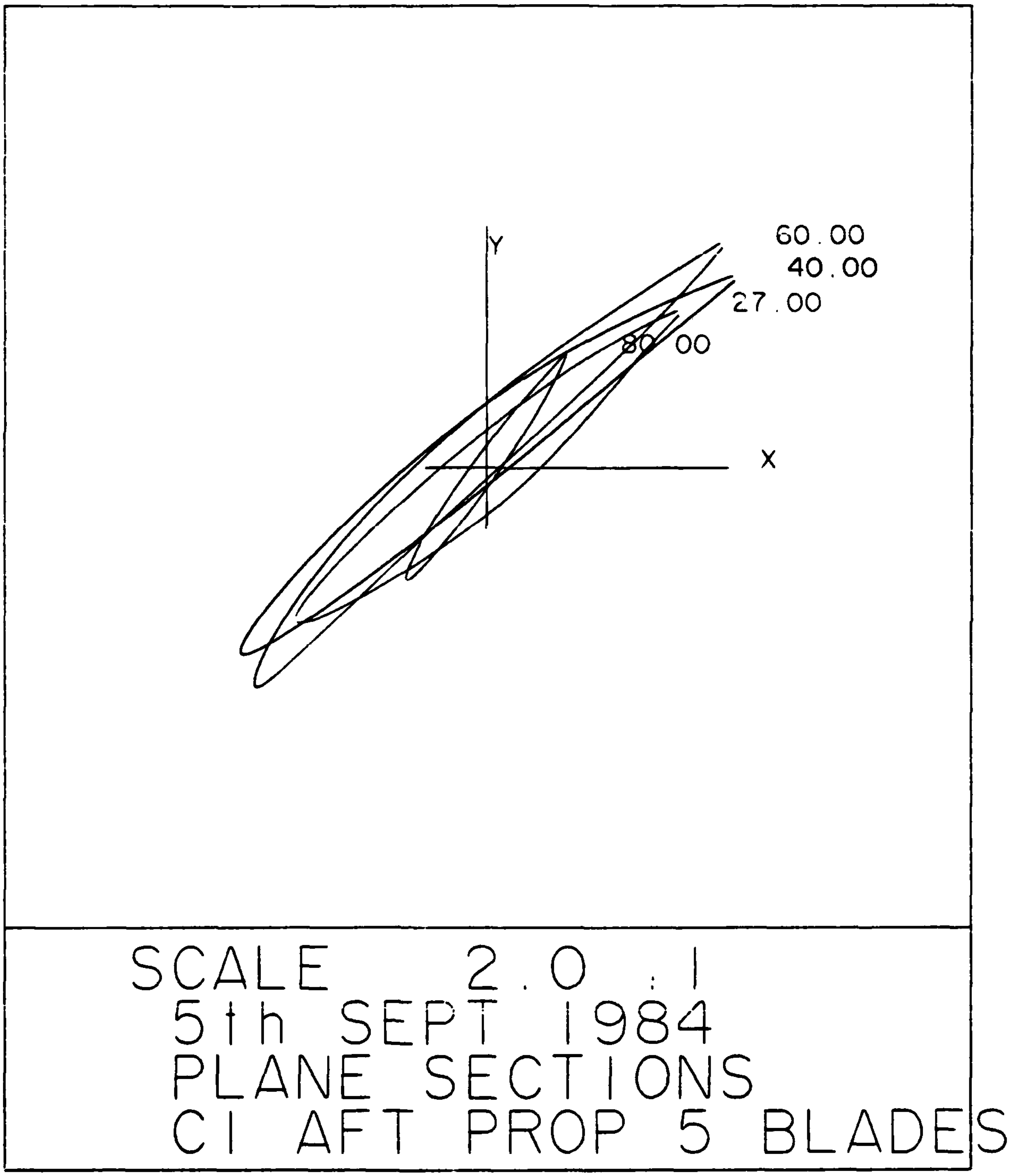
X	Y	X	Y
-38.4510	-36.5444	-38.4510	-36.5444
-38.6494	-36.2640	-38.1149	-36.6126
-38.6841	-36.0899	-37.9425	-36.5743
-38.6968	-35.7767	-37.6531	-36.4627
-38.6724	-35.4861	-37.4002	-36.3291
-38.6270	-35.2051	-37.1649	-36.1870
-38.5016	-34.6686	-36.7230	-35.8803
-38.3462	-34.1482	-36.3045	-35.5595
-37.9734	-33.1373	-35.5081	-34.8969
-37.5517	-32.1514	-34.7323	-34.2217
-37.0877	-31.1884	-33.9733	-33.5343
-36.0871	-29.2985	-32.4611	-32.1497
-35.0074	-27.4531	-30.9539	-30.7467
-33.8731	-25.6427	-29.4438	-29.3248
-32.6883	-23.8504	-27.9364	-27.8933
-31.4568	-22.0772	-26.4282	-26.4551
-29.5365	-19.4516	-24.1515	-24.2931
-27.5350	-16.8719	-21.8626	-22.1196
-25.4624	-14.3370	-19.5613	-19.9369
-23.3335	-11.8436	-17.2456	-17.7448
-21.1431	-9.3834	-14.9225	-15.5547
-17.3711	-5.3746	-11.0241	-11.9147
-13.4754	-1.4916	-7.0838	-8.2759
-5.3775	5.9356	.8339	-.9798
3.0916	12.8875	8.7590	6.3159
11.8129	19.3841	16.6398	13.6405
20.6708	25.4473	24.4073	21.0377
29.5116	31.2053	31.8374	28.5958
33.8960	34.0047	35.3431	32.4398
36.5055	35.6661	37.3625	34.7642
38.2346	36.7674	38.6674	36.3209

HEIGHT 80.000

X	Y	X	Y
-13.1591	-18.8417	-13.1591	-18.8417
-13.2523	-18.7508	-13.0172	-18.8537
-13.2698	-18.6825	-12.9532	-18.8419
-13.2907	-18.5763	-12.8364	-18.7890
-13.2900	-18.4696	-12.7393	-18.7370
-13.2842	-18.3699	-12.6473	-18.6772
-13.2559	-18.1735	-12.4789	-18.5535
-13.2149	-17.9816	-12.3202	-18.4245
-13.1087	-17.6050	-12.0195	-18.1559
-12.9837	-17.2317	-11.7284	-17.8791
-12.8427	-16.8615	-11.4451	-17.5940
-12.5341	-16.1179	-10.8839	-17.0096
-12.1924	-15.3698	-10.3271	-16.4075
-11.8260	-14.6167	-9.7696	-15.7869
-11.4379	-13.8552	-9.2115	-15.1505
-11.0302	-13.0862	-8.6509	-14.4978
-10.3863	-11.9133	-7.8042	-13.4924
-9.7012	-10.7220	-6.9499	-12.4581
-8.9783	-9.5182	-6.0857	-11.3960
-8.2228	-8.3018	-5.2108	-10.3055
-7.4404	-7.0758	-4.3263	-9.1857
-6.0853	-5.0109	-2.8410	-7.2601
-4.6711	-2.9274	-1.3506	-5.2741
-1.7032	1.2183	1.6217	-1.1608
1.3531	5.2627	4.4764	3.0731
4.4297	9.1068	7.1402	7.2869
7.4449	12.6827	9.5313	11.3681
10.3352	15.9422	11.5979	15.2264
11.7141	17.4591	12.4820	17.0476
12.5200	18.3315	12.9672	18.1003
13.0475	18.8979	13.2707	18.7854

A P P E N D I X   G

Test example 2 - plotter output



END

FILMED

12-85

DTIC